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REPORT ON THE UNITED NATIONS/EUROPEAN SPACE AGENCY WORKSHOP ON BASIC SPACE SCIENCE FOR DEVELOPING COUNTRIES, ORGANIZED IN COOPERATION WITH THE GOVERNMENT OF INDIA AND HOSTED BY THE INDIAN SPACE RESEARCH ORGANIZATION

(Bangalore, India, 30 April-3 May 1991)

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INTRODUCTION

A. Background and objectives

1. The General Assembly, at its thirty-seventh session, adopted resolution 37/90 of 10 December 1982, endorsing the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) that the United Nations Programme on Space Applications should promote the growth of indigenous nuclei and an autonomous technological base in space technology at the local level. At its thirty-third session, in June 1990, the Committee on the Peaceful Uses of Outer Space endorsed the United Nations Programme on Space Applications for 1991 as proposed by the Expert on Space Applications and recommended by the Scientific and Technical Subcommittee of the Committee at its twenty-eighth session. Subsequently, the General Assembly, at its forty-fifth session, endorsed the activities of the Programme on Space Applications for 1991 (resolution 45/72 of 11 December 1990).

2. The first United Nations/European Space Agency (ESA) Workshop for the benefit of developing countries was part of the 1991 activities of the Space Applications Programme. The Workshop was co-sponsored by ESA, organized in cooperation with the Government of India and hosted by the Indian Space Research Organization at Bangalore, India, from 30 April to 3 May 1991.

3. The objective of the Workshop was to strengthen basic space science in developing countries by addressing the ways and mechanisms through which the following goals could be accomplished:

(a) To improve the awareness of scientists about current and future scientific and technical aspects of basic space science;

(b) To enhance scientific cooperation among developing countries, including the exchange of scientific information;

(c) To explore avenues of education, training and research on space science subjects for the benefit of developing countries;

(d) To create on international core group of scientists to pursue the objective of the Workshop.

4. The present report, which covers the background, objectives and organization of the Workshop, as well as a summary of presentations, observations and recommendations made at the Workshop, has been prepared for the United Nations Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. Participants of the Workshop will report to the appropriate authorities of the Government, universities and research institutes in their respective countries.

B. Organization and programme of the Workshop

5. Invitations to participate in the Workshop were sent by the United Nations to scientific professionals with substantial experience in one or more of the following areas: (a) basic space science and development; (b) earth science; (c) solar-terrestrial interaction; (d) solar system science; and (e) space astronomy and astrophysics. The Workshop was attended by 87 experts from 19 countries and 2 international organizations. The participants came from Afghanistan, Canada, China, Czechoslovakia, Egypt, India, Indonesia, Japan, Kenya, Mongolia, Nigeria, Oman, the Philippines, Spain, Sri Lanka, Thailand, the United Kingdom of Great Britain and Northern Ireland, the United States of America, Viet Nam, ESA, the International Centre for Theoretical Physics (ICTP), Trieste, and the United Nations Outer Space Affairs Division.

6. Funds allocated by the United Nations and ESA for the organization of the Workshop were used to cover the cost of international air travel for 19 participants. The Government of India provided the Workshop facilities, room and board for 19 participants and local transportation for the duration of the Workshop.

7. Welcoming addresses were made by Dr. K. Kasturirangan, Director, Satellite Centre of the Indian Space Research Organization (ISRO); Prof. U. R. Rao, Chairman, Space Commission of the Government of India, on behalf of ISRO; Prof. M. G. K. Menon, President of the International Council of Scientific Unions (ICSU), on behalf of the Government of India; and Mr. N. Jasentuliyana, Chief, Outer Space Affairs Division, on behalf of the United Nations.

8. The scientific programme of the Workshop (see annex I) was developed by the United Nations Outer Space Division in collaboration with ESA and ISRO. The Workshop was scheduled to have three days of plenary sessions and two parallel special sessions with presentations by invited speakers only. The sessions of the Workshop were held in an informal style, leaving enough time for informal discussions and a few ad hoc contributions from participants. The afternoon of the third day, Thursday, 2 May, and the morning of the fourth day, Friday, 3 May, were exclusively reserved for working group sessions where the participants discussed in depth the national capabilities to develop programmes and to undertake research activities in basic space science and ways to foster international collaboration in the field, respectively. The proceedings of the Workshop will be published in the Conference Proceedings Series of the American Institute of Physics (AIP), New York.

I. OBSERVATIONS AND RECOMMENDATIONS

A. Basic space science

9. Based on suggestions by participants, the following areas of research were defined as parts of basic space science:

(a) Fundamental physics;

(b) Astronomy and astrophysics;

(c) Solar-terrestrial interaction and its influence on terrestrial climate;

(d) Planetary and atmospheric studies;

(e) Origin of life and exobiology.

10. Participants agreed that the following techniques would be applicable for pursuing basic space science research:

(a) Ground-based optical, infrared and radio observations and radio and optical telescopes with associated equipment;

(b) Remote sensing, both from the ground and from space;

(c) In-situ measurements from rocket, balloon and satellite platforms;

(d) All measurements from ground-inaccessible windows which can be made only through the use of instruments and telescopes in Earth orbit;

(e) Phased radar techniques.

B. Availability and dissemination of scientific information

1. Availability of information on major space science projects

11. The United Nations urges the major space agencies of the world to supply advanced information regarding various projects to scientists in developing countries so that those scientists can involve themselves in follow-up studies.

12. Considering the very high price of scientific journals and the rise in the exchange rate of hard currencies, the United Nations will strive to investigate the possibility of defining a per capita limit below which institutes in developing countries might benefit from the existing reduced subscription rates of professional and popular journals. Alternative routes to enhance the availability of this critically important information in developing countries should also be investigated.

13. The United Nations will inquire into, in association with the activities already being carried out by the International Astronomical Union (IAU), ICTP, European Physical Society (EPS) and AIP, the severe difficulties encountered by researchers in acquiring textbooks, conference proceedings and other materials needed to maintain forefront scientific research. This could also include contributions sought through discussion with commercial and technological industries.

2. Data archives and data centres

14. The United Nations recognizes the importance of the availability at the national level of the existing basic space science data archives for building up first-rate educational and research capabilities for internationally recognized scientific investigations.

15. The United Nations therefore urges Member States to select, through internal (national) discussion, local or regional clearing-houses for the highly valuable data archives that are still available at no cost from their producing agencies. The owners should be requested to deliver such data products in a manner conducive to easy dissemination and access at national levels; e.g. the IUE (International Ultraviolet Explorer Uniform Low Dispersion Archive (ULDA)). These clearing-houses (or data centres) will foster the development of national basic space science resources and stimulate international collaboration through the existence of common interest centres. These centres will also make highly valued data pertaining to individual countries more accessible to other Member States and consequently enhance awareness of the capabilities of each country.

3. Information management system

16. The United Nations will act to establish an information management centre serving as both a source of information on current activities in basic space science and as a source of information for those searching for new initiatives in the field to identify and inform interested collaborators in the developing countries.

17. The United Nations will inquire with institutes and researchers into the availability of the above information. This will include the collection of detailed information on bilateral and multilateral arrangements allowing the exchange of students and researchers both for learning as well as for teaching purposes.

18. Recognizing that a country's level of involvement in the activities in basic space science is invariably associated with existing economic conditions, the United Nations recommends the development of new initiatives originating in developing countries for deeper involvement in basic space science. It recognizes, however, that such new initiatives should be accommodated within the individual infrastructural envelope of the country. It will therefore strive to explore ways and means through which vital issues for a continued evolution of individual (country) basic space science activities and international cooperation could be maintained and stimulated.

4. Electronic communication network

19. The United Nations recognizes that the rapid pace of change in basic space science and technology makes the free and efficient flow of ideas an

concepts a prime need for participation in basic space science and therefore urges Member States to plan and implement local electronic communication at or above the level of E-mail networks. Once implemented, or even before the existence of a local (national) network, an internet/uunet/bitnet connection should be established at a suitable location.

20. The United Nations requests Member States to identify support needs without which the above-mentioned facilities cannot be implemented and will act to identify and possibly supply limited funding needed to support justified requests for the minimum necessary investment to start the implementation of the fundamental needs associated with this (identified as PC/AT computers class with 100-300 MB of memory, communication I/A modem and annual connection fee).

5. Use of available scientific databases

21. The United Nations recognizes the importance of access to advanced instrumentation and modern extended data sets for the evolution of basic space science disciplines and urges its Member States and their scientists to utilize those facilities that are currently available. Much of this could be accomplished through the utilization of existing available databases (such as exist for IUE and EXOSAT), but additional direct use of these facilities would add critical emphasis to the development of countries currently missing familiarity with the capabilities of these facilities.

22. The United Nations requests the scientific institutes that are operating major basic space science facilities to respond to and support requests from developing countries for access to advanced instrumentation and to overcome, in all ways within their capabilities, the perceived problems of gaining access to their facilities.

C. Availability and establishment of scientific facilities

1. Utilization of infrastructural facilities

23. In order to stimulate the utilization of the existing major facilities in basic space science by scientists from developing countries and to enhance their awareness, the United Nations will:

(a) Encourage countries having better facilities in the developed world to open their facilities to other developing countries;

(b) Provide short-term fellowships and travel grants for such purposes;

(c) Consider the establishment of a central facility in the form of United Nations international/regional institute(s).

2. Utilization of ground-based facilities available in developing countries

24. Considering (a) that many developing countries already have a number of medium-sized telescopes that are suitable for research activities if they could be equipped with modern instruments; (b) that there are countries where there is a great demand for telescope time; and (c) that there is technology available in some developing countries to build the instruments to be used with existing telescopes, the United Nations will encourage Member States:

(a) To share the existing telescopes with the astronomers from the region;

(b) To develop advanced instrumentation which will improve the efficiency of the existing telescopes;

(c) To develop methods which will improve the efficient use of these facilities.

25. The United Nations will endorse and coordinate similar efforts that are being pursued by the IAU Commission No. 46 for Teaching of Astronomy and for funding travels of astronomers to use these facilities.

3. International institute on basic space science

26. Considering the expected rapid growth and scientific returns for developing countries resulting from a concerted programme in basic space science and expecting that regional and international cooperation would continue to be the main aspects of such an outcome, the United Nations will inquire into the establishment of an international institute of basic space science in a developing country to service such requirements. Such an institute could be thought of along the pattern of ICTP.

27. The United Nations could also consider another mechanism of realizing such a goal by setting up such centres on regional bases for cooperation among developing countries.

D. International cooperation in basic space science

1. International cooperation and internationally coordinated basic space science programmes/projects

28. The United Nations recognizes that the benefits of the pursuit of basic space science investigations constitute a prime mover of collaboration between Member States and therefore supports and recommends:

(a) Further expansion and continuation of studies of Equatorial Electrojet (EEJ) in the context of regional/international collaboration involving:

(i) The reactivation of selected geomagnetic and ionospheric observatories, as well as enhanced support of the networks of such observatories;

(ii) The encouragement of active scientists to participate in international meetings;

(iii) The creation of national committees for the Committee on Space Research (COSPAR) for those Member States not already belonging to that organization, which is a major venue for the coordination of studies in the field;

(b) The augmentation of the global coverage of INTERMAGNET by supporting the establishment of:

(i) Three observatories in Sri Lanka, eight in Africa and eight in South America;

(ii) A regional geomagnetic information node (GIN) at the Indian Institute of Geomagnetism, Bombay;

(c) The establishment of a regional information centre specifically oriented toward atmospheric sciences with the purpose of:

(i) Disseminating all relevant data obtained under basic space science activities such as remote sensing and atmospheric probing to provide vital regional information of fundamental importance for addressing problems related to disaster avoidance and warning;

(ii) Developing a new understanding of the globally important equatorial zone and therefore developing a plan (in the developing countries) leading to improved resource management and an expected improvement in living conditions;

(d) Strengthening and reorienting of the current research activities in the fields of solar-terrestrial, atmospheric and climatic studies, combined with space remote-sensing observations to pursue the internationally coordinated Geosphere/Biosphere Programme (IGBP), which includes:

(i) Satellite observations to assess pollutant-rich areas;

(ii) Ground and air truth measurements of solar radiation related to a variety of minor constituents;

(iii) Physical understanding and mathematical modelling of the interlinked processes of global change;

(iv) Specific unresolved aspects of the energetics of the solar-terrestrial system under the Solar Terrestrial Energy Programme (STEP).

2. Meetings and symposia on basic space science

29. Considering the growing interest and contribution made by several developing countries in basic space science and the need for further encouraging such activities, the United Nations will:

(a) Organize international meetings for in-depth discussions on specific topics of basic space science;

(b) Organize international basic space science symposia, the first of which could be held in China and co-sponsored by the United Nations.

3. Continuation of the workshop on basic space science

30. In order to assure a continued and coordinated evolution of the important issues raised at the current workshop, it is proposed to hold the next few basic space science workshops annually, although in the long run they should be held no more than biannually.

31. The United Nations will act as soon as the delegates from Oman and Sri Lanka have inquired with their authorities into the possibilities of hosting basic space science workshops in 1992 and 1993, respectively.

4. Space education

32. Considering that basic space science is not taught at superior levels in many developing countries, the United Nations will act to encourage and support:

(a) The introduction of the teaching of basic space science as a part of the curriculum for graduate and post-graduate studies;

(b) Formation of research facilities at universities so that motivated students could be encouraged to pursue basic space science research;

(c) The conduct of summer schools and other similar orientation programmes to train the existing faculty in the physical sciences necessary to teach basic space science;

(d) The exchange of teachers, scientists and research workers to make use of the facilities in Member States and the services of organizations such as IAU and COSPAR;

(e) The conduct of seminars, workshops and topical conferences within the developing countries for the benefit of teachers, scientists and researchers;

(f) The introduction of popular programmes to encourage and support awareness of basic space science and coordinate such activities with Member States;

(g) Programmes ensuring the availability of basic textbooks and more popular information media at the professional and general public levels;

(h) The generation of national career opportunities for professionals trained under the above-mentioned programmes, leading to the increased competitiveness of developing countries in the peaceful study and utilization of resources associated with basic space science.

5. International core group

33. In order to pursue and follow up the recommendations made during the Workshop it has been decided to constitute a core group of international scientists consisting of the following members at the functional and advisory levels:

Functional members: China, India, Kenya, Nigeria, Oman, Philippines, Sri Lanka, Venezuela

Advisory members: COSPAR, ESA, IAU, ICTP, National Space Development Agency (Japan) (NASDA), National Aeronautics and Space Administration (United States of America).

II. SUMMARY OF PRESENTATIONS

A. Basic space science: a challenge and opportunity

34. Historically determined the domains of meteorology and astronomy are considered to belong to the field of space science. Whether science in space, using balloons, sounding rockets, aeroplanes, spacecraft and satellites, or science from space, employing remote-sensing techniques, they are subsumed by the term "space science". The development and construction of the instruments to be used for applied and basic space science are covered by space technology. Basic space science is the research-oriented part of all fields subsumed by the term "space science", including those listed in paragraph 9 above.

35. For a long time it was believed that modern science offered the only way to shorten the time to bridge the technological, economical and educational gap between developing countries and industrialized nations. However, in order that the developing countries can partake in the benefits inherent in science, there must be an adequate and long-term investment in the development of research and education activities in the respective disciplines at the local level. In the initial phase of this process, scientific research in a developing country should have the only goal to allow its scientific groups to

achieve a critical mass while maintaining strong international cooperation in the field. Basic space science is particularly suited for this purpose in offering a balanced mix of basic research in mathematics, physics, astronomy and technology and education, respectively.

36. The approach to space science taken by India constitutes a model for developing countries. The Space Commission and the Department of Space of India were established by the Government of India in 1972 to provide unified development and application of space science and technology for identified national objectives. The Indian Space Programme is directed towards the goal of self-reliant use of space technology for national development. ISRO is the research and development wing of the Department of Space of India and is responsible for the execution of the national space programme. Additionally, ISRO provides extensive support to universities and other academic institutions in India for research and development projects relevant to the country's space programme, including basic space science.

37. Basic space science has become a highly important human activity, exerting an ever-growing influence on aspects of life in modern society. Major scientific discoveries and achievements made during the last decades by the breakthrough into outer space have a profound impact on the development of production, on social consciousness and finally on the internationalization of science. In the context of the growing impact of science on modern society, there is clearly a need for international cooperation, in an increasing global interdependence, in basic space science for the benefit of both industrialized and developing countries. Developing countries should also be given the means of being an equal partner in a world-wide prospectus in basic space science, while honouring their cultural heritage and scientific tradition.

38. Space programmes world wide are approaching a turning point in the scale and nature both of manned and unmanned missions. As an example, in Japan human ventures into outer space have been focused in the past primarily on missions of observation, experimentation and launching of telecommunications satellites or scientific instruments. However, current trends show that the space community stands at the threshold of multiple manned missions to construct permanent space stations and make practical use of the space environment. Japan is joining other space nations in taking the lead to accomplish this challenge. Here again it should be underlined that the science of today is the technology of tomorrow and that for bridging the technological, economical and educational gap between industrialized and developing countries advanced space programmes must be carried out on an international scale, particularly seeking contributions from developing countries.

39. As one of the oldest of the natural sciences, astronomy has advanced mankind's understanding of various cosmic phenomena and has contributed to the systematization and discovery of fundamental laws of physics. In recent years, the introduction of large-scale observational facilities, the development of new observation techniques, increased precision in calculation

methods and the expansion of international joint-research projects resulted in remarkable advances in astronomy and related fields. On the national level there is a trend to establish national astronomical observatories as interuniversity research institutes for astronomical research. They may act as facilitators of international cooperation in the field of astronomy and promoters of international exchange programmes and international joint-research projects. On the international level there is a growing awareness of the need to promote the establishment of a world institute for astronomy to be organized by scientists, administrators and statesmen from the United States, the Soviet Union and from any other country that may wish to participate scientifically and financially.

40. Technology in modern society cannot flourish without science flourishing at the same time. For long-term effectiveness, technology transfer must always be accompanied by science transfer. The importance of scientific research to the well-being of the nation has long been recognized by policy-makers in industrialized and developing countries. There is less awareness, however, of the fact that basic space science represents an ideal convergence of physics, mathematics, astronomy, applied science and interdisciplinary research, thus offering an excellent training field for scientists, who can later transfer the acquired experience to other endeavours such as those directly related to the economic and social needs of a nation.

B. Solar-terrestrial interaction

41. IGBP is promoting an interdisciplinary approach to studies of the Earth system. Its objective is to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system and the manner in which they are influenced by human activities. IGBP is a major international project of ICSU.

42. A particularly important subtopic of IGBP is the integration and synthesis of the available knowledge of components of the Earth system in a numerical framework that provides predictive capacity. With the aid of models, a fundamental qualitative understanding of the global physical, chemical and biological interactions in the Earth system during the last 100,000 years should be synthesized and possible effects of future changes should be assessed. For this purpose, computers as complete scientific instruments in themselves and supercomputers that are technologically the most powerful computers available for scientific calculations at any given time have to be employed.

43. Upper atmospheric research satellites (UARS) are aimed at improving knowledge of the stratosphere, mesosphere and lower atmosphere and emphasizing those levels that are known to be particularly susceptible to change by external agents. Using a continuation of measurements and theoretical studies, UARS will provide a focus for the resolution of scientific questions relating to the chemistry, dynamics and overall energy balance of this region.

44. Scientists have become increasingly concerned about the sensitivity of the Earth's atmosphere to changes caused indirectly by various human activities. Long-standing curiosity about atmospheric evolution and the factors influencing climate and weather has been sharpened and refocused by the discovery of technologically-related research that introduce the possibility of inadvertent atmospheric modification. Particularly, there is a need to make clear where astronomy is developing and to make clear how man-made noise impacts on astronomical observations, an enterprise made difficult by the Earth's own atmosphere.

45. There happens to be a concentrated stream of electricity of limited width, believed to be produced by an intensification of atmospheric electric sheet currents usually present over the magnetic poles and forming the boundaries of the zones of the aurorae. There is a strong electrojet flowing westward on the morning side of the Earth, and a weaker one flowing eastward on the evening side, with a zero-current area where the two meet.

46. The ionosphere-thermosphere system of the equatorial region has distinctly different characteristics owing in part to the relatively larger fraction of the solar radiant energy absorbed in the tropical latitudes and in part to the Earth's quasi-horizontal magnetic field vector. The dynamic, electrodynamic and plasma processes peculiar to this region produce the well-known features of the coupled equatorial ionosphere-thermosphere system: (a) the equatorial ionization anomaly (EIA), (b) EEJ, and (c) the equatorial plasma bubble/spread-F irregularities.

47. Atmospheric concentrations of several trace gases are increasing rapidly, mainly as a result of human activities. Increases in so-called greenhouse and other trace gases result in changes in the composition of the atmosphere, thus affecting physical aspects of the climate system. These gases interact in the stratosphere resulting in alteration in the chemical composition, radiation and dynamics in the stratosphere and potentially affect the lower troposphere and even the biotic system via modulations of the solar ultraviolet band (UVB) radiation received at the Earth's surface. Many of these gases are produced biologically or affect biological processes. The sources and sinks of important chemical components of the atmosphere and their interactions with living organisms need to be identified and qualified. An understanding of the key processes regulating the composition of the atmosphere and feedback mechanisms that affect the behaviour of the system is necessary.

C. Solar system science

48. The solar system provides a vast laboratory for mankind to gain insight into various fundamental processes. The advent of satellites for basic space science missions has revolutionized such disciplines as solar and heliospheric physics and space plasma physics. Solar system science comprises the investigation not only of the components *per se* - the sun, the planets, the moons, the space plasma and the atmospheres - but also the study of the linear

and non-linear interactions between its components. The sun, which forms the centre of the solar system, spends the energy for all life on Earth. For an understanding of how the solar energy output is changing over time, it will be necessary to observe the sun over long periods of time with appropriate instrumentation. This can be done with new developments in ground-based observations and the utilization of opportunities now available in spacecraft missions.

49. The sun plays a central role in calibrating and testing the theory of stellar structure and evolution, which forms a cornerstone of astrophysics. A powerful diagnostic tool, helio-seismology, has become available in recent years, whereby observed frequencies of solar oscillations are used to study the solar interior. The rich spectrum of sound waves and gravity waves travelling through the sun makes it possible to discover a great deal about the variation of the speed of sound, the speed of rotation and the chemical composition with radial distance from the centre. Helio-seismology may even make a contribution to the understanding of the gravitationally stabilized fusion reactor sitting in the central part of the sun. For the necessary measurements to be made, the sun must be observed continuously for a long time, without the interruptions of nights. An international network of instruments for this purpose, to be spaced around the globe in such a way that the sun will nearly always be shining on at least one of them, has to be set up. Also the availability of advanced, dedicated spacecraft missions will be of central importance in this regard.

50. Extreme ultraviolet light from the sun cannot be collected and focused usefully with telescopes of conventional design. Experimental extreme ultraviolet (EUV) telescopes flown on manned spacecraft, unmanned sounding rockets, and interplanetary probes have collected data about the solar EUV emission. To attempt to identify the characteristics of energy sources and driving forces in the solar corona, special missions have been flown. Particularly by observing the rich EUV spectrum between 240° A and 450° A, a region with numerous emission lines of highly ionized magnesium, silicon and iron, each produced over a relatively narrow band of plasma temperature, scientists can characterize the corona over the solar disk without interference from the 6,000K black-body radiation from the sun's photosphere. Spectral signatures of all EUV-emitting features along the centre lines of the images have been recorded. These data can be used to derive information on the density, temperature and dynamic states of the plasma. Combination of images and spectral data provides insight into the mechanisms that produce and sustain highly confined loops of plasma in the solar corona.

51. Solar-wind physics is closing the gap between solar physics and interplanetary physics. Corpuscular emissions from the sun that impinge on the Earth are highly variable and have significant effects on the geosphere. A subject of intensive research is to find an understanding of the energy, momentum and mass transfer mechanisms across shocks and the boundaries that separate the distinct plasma regions of the solar-terrestrial system and to study the acceleration, diffusion and convection processes and large-scale instabilities that distribute and modify the complex corpuscular flows, plasma waves and fields in the coupled solar-wind/magnetosphere/ionosphere system.

52. The steady flow of the solar wind is intercepted by the Earth's magnetic field which, as a result, is deformed into a huge, comet-like configuration, the magnetosphere, filled with plasma from the solar wind and the Earth's upper atmosphere. The magnetosphere is not in a stationary equilibrium state. Partly driven by perturbations in the solar wind, partly responding in a chaotic form when the accumulation of energy in the magnetotail exceeds some intrinsic threshold, the magnetosphere undergoes global changes by restructuring its plasma distribution and magnetic field. These processes lead to manifestations detectable on the ground that have been known for a long time, such as auroras, magnetic storms and auroral substorms. Key unanswered questions refer to the relative importance of the sources of magnetospheric plasma particles in the solar wind and ionosphere and pertinent injection mechanisms. Unresolved questions concern the generation of the ring current and van Allen radiation belt; the global problem of coupling between the solar wind, the magnetosphere and the ionosphere; and the physics of the micro- and meso-scale processes responsible for this coupling.

53. The solar corona consists of open magnetic regions, called "coronal holes", whose detailed physical characteristics are not well known, and closed magnetic regions. The latter show up as a highly intertwined collection of hot loops, whose thermal and magnetic structure and stability are a very active area of research. Many basic features of prominences are also not understood: their overall magnetic structure, their fine-scale thread-like thermal structure, their complex velocity patterns, their long-term stability and their formation, evolution and disappearance.

D. Space astronomy and astrophysics

54. For centuries, the only accessible wavelength region for astronomical observations was a tiny slit in the electromagnetic spectrum: the visual part ranging from approximately 400 to 800 nanometres wavelength. About 50 years ago, it was established that observations in the radio domain of the electromagnetic spectrum were quite promising and of great potential influence on existing astronomical concepts. With the advent of the space age, the absorbing effects of the Earth's atmosphere could be entirely circumvented and the entire electromagnetic spectrum became accessible for astronomical observations: from radio waves to gamma rays. In more recent times even new observational horizons have opened up through neutrino astronomy and gravitational wave astronomy.

55. Cosmologists, particle physicists and astronomers are reaching, through observation and theory, the opinion that nine tenths of the mass of the universe may be in an entirely different form than the ordinary stars and galaxies with which astronomers have long been familiar. This matter, only manifested by its gravitational effects within and between galaxies and clusters of galaxies, is in a form as yet unseen, not only in visible radiation, but also in radiation in all other wavelength ranges opened up by the advent of the space age. The crucial question appears which the basic building blocks of the universe are and whether they are tracing the

large-scale distribution of matter in the universe. It remains to be shown that stars and galaxies are indeed these basic building blocks.

56. The Cosmic Background Explorer (COBE) satellite, launched into a polar orbit in November 1989, observes the remnants of the big bang explosion that formed the universe and searches for data on the formation of the first galaxies and quasars. COBE, a project of the Goddard Space Flight Center of NASA, carries three scientific experiments: (a) the differential microwave radiometer (DMR) measures the isotropy of the 2.7K cosmic background radiation; (b) the far infrared absolute spectrophotometer (FIRAS) examines the spectrum of the cosmic background radiation over the whole sky, searching for deviations from the thermal character predicted by theories of the big bang; and (c) the diffuse infrared background experiment (DIRBE) observes the sky at 10 infrared wavelengths short of the cosmic background radiation. Its goal is to look for evidence of the earliest galaxy formation.

57. A final discovery of granularity in the microwave background radiation will lead to an important progress in the understanding of the seed inhomogeneties that eventually become galaxies and quasars. FIRAS on COBE, measuring the spectrum of the big bang, has confirmed that there is no hint or trace of massive energetic processes that must have created the structure of the present universe, filled with enormous voids and huge concentrations of galaxies, such as the recently discovered great attractor.

58. Radio astronomy is revealing a universe dramatically different from the vision of relative stability and tranquillity seen in visible light. Using a variety of radio telescopes, radio astronomers have discovered many exotic types of objects, such as radio galaxies, quasars and pulsars, which are strong sources of radio waves. These radio waves generally arise from highly energetic electrons and magnetic fields that are created in the aftermath of violent and catastrophic events occurring in star explosions and in ultra-strong gravitational fields in the central regions of galaxies.

59. There are two aspects of radio astronomy that require operation from space. First, the addition of one, or more, orbiting antennae to the ground-based very long baseline arrays (VLBA) would double or triple the spatial resolution of that network. Second, there is the opportunity to open a new spectral window at very low frequencies with a space array.

60. By lofting scientific instruments into outer space, above the atmosphere that screens out most radiations, astronomers have managed to observe at all bands of the electromagnetic spectrum, from radio and infrared to ultraviolet and X-ray wavelengths. Each kind of radiation provides a special perspective on celestial vistas and yield new discoveries in astrophysics and cosmology. Four great observatories are planned or operating to study radiation across the electromagnetic spectrum. Gamma rays will be captured by the Gamma Ray Observatory (GRO) and the spacecraft GRANAT revealing the story of the birth of chemical elements and the death of stars and the structure at the centre of the Milky Way of enigmatic quasars, pulsars and neutron stars. The Advanced X-ray Astrophysics Facility (AXAF), which will be launched in 1998, is

dedicated to the study of gas clusters and streams. The Hubble Space Telescope (HST), launched in 1990, observes visible and ultraviolet light emitted in the process of the formation and evolution of stars. Finally, the proposed Space Infrared Telescope Facility (SITF) will cover the observation of infrared and radio waves emitted by stars and galaxies and left over from the big bang.

61. Neutrinos are weakly interacting particles emitted in the hottest and densest regions of cosmic bodies. The fact that matter is practically transparent for neutrinos makes the neutrino a probe to explore the deep interior of optically thick objects such as stars. The best known example is provided by the flux of solar neutrinos which is surprisingly only one third of the flux expected by model calculation. The recent observation of neutrino bursts associated with the supernova SN 1987A has proven the importance of neutrino observatories for the detection of cosmic neutrinos. Because neutrinos were present in large numbers in the early universe, their properties may affect the evolution and the present structure of the universe. Knowledge about the history of the universe thus can be used for placing limits on the mass, lifetime and number of flavours of neutrinos.

62. Astronomers have had one main road to understand the universe: to disclose the information carried by electromagnetic radiation. However, all types of electromagnetic radiation are due to the same fundamental physical process, the acceleration of electric charges. Additional to the electromagnetic window there are the neutrino radiation and cosmic rays. Cosmic objects are surface sources of electromagnetic radiation but volume sources of neutrinos. Within the next few years several new ground-based and space-based observatories will start to pick up an entirely new kind of signal from space: gravitational waves. Those gravitational waves are ripples in space-time itself spreading through the universe, distorting the shape of any object they pass through. The astrophysics involved in generating gravitational waves concerns the non-symmetric collapse of massive stars, binary stars containing a neutron star, coalescing star pairs and disappearing loops of cosmic strings.

63. The International Ultraviolet Explorer (IUE) has been observing astronomical spectra almost continuously since its launch into a geosynchronous orbit in January 1978. For more than 13 years, IUE has been the only orbiting instrument capable of obtaining ultraviolet spectra in the region from 1,200° A to 3,000° A. The prodigious scientific output of IUE is attributable to the uniqueness of this research opportunity and to IUE's capability for measuring a very wide region of the spectrum in a single exposure. Continuous observation of planets in the solar system, detection of stellar variability and regular monitoring of active galactic nuclei will remain dominant fields of IUE in the future.

E. The search for life beyond Earth

64. Life emerged on Earth during the first billion years that followed the formation of planet Earth. Although the detailed scenario is still a subject of intense discussion, it is well established that the phenomenon of life arose from non-living matter through a long chemical evolution. It involved two key ingredients: (a) carbon components and (b) liquid water. Starting from simple organics or their oligomers, through physical and chemical processes, prebiotic chemistry progressively gave rise to the building blocks and to the macromolecules of the living systems.

65. Observations in the infrared and the submillimeter are one of the few ways by which one can begin to understand how life arose in the universe. Currently, a self-consistent outline is emerging of the pathways leading from stellar nucleosynthesis of carbon, oxygen, nitrogen, phosphorus, sulfur and other biologically significant trace elements to their inclusion into planetesimal-sized bodies within the young protosolar nebula. Interstellar dust plays an important role in the cosmic evolution of biogenic elements. Interstellar grains show a diverse chemical composition, including refractory materials such as silicates, graphite and amorphous carbon, often coated inside molecular clouds by water-rich ices or ices containing much more complex molecules such as alcohols, aldehydes and ketones. Furthermore, the size distribution of interstellar amorphous carbon grains may extend well into the molecular domain and complex polycyclic aromatic hydrocarbons may be very abundant, forming the necessary link between carbon dust grains and simple gas phase molecules.

Annex

PROGRAMME OF THE WORKSHOP

Venue: ISRO Satellite Centre, Bangalore

DATE/TIME	SUBJECT	SPEAKER
30 APRIL 1991		
8-9 a.m.	Registration	
	Plenary session 1: Inauguration and opening ceremony	
9-9.10 a.m.	Welcome address	K. Kasturirangan
9.10-9.30 a.m.	United Nations address	N. Jasentuliyana
9.30-10 a.m.	Inaugural address	M. G. K. Menon
10-10.40 a.m.	Keynote address: Importance of basic space science for developing countries	U. R. Rao
10.40-10.45 a.m.	Vote of thanks	M. G. Chandrasekhar
10.45-11 a.m.	Break	
	Plenary session 2: Basic research in developing countries	
	Chairman: Y. Kozai	
11-11.45 a.m.	Space exploration: the challenge and the opportunity for developing countries	R. Khanna (United States of America)
11.45 a.m.-12.30 p.m.	International cooperation in basic sciences: its significance for developing countries - a personal experience	A. M. Mathai (Canada)
12.30-1.45 p.m.	Lunch hosted by the Director, Raman Research Institute, Bangalore, at Workshop venue	

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DATE/TIME	SUBJECT	SPEAKER
	Special session SSS-1: Solar system science	
	Chairman: A. P. Mitra	
1.45-2.30 p.m.	High resolution extreme ultraviolet (EUV) studies of the sun	S. K. Jain (ESA)
2.30-3.15 p.m.	Long-term solar variability and solar seismology: I	H. A. Hill (United States of America)
3.15-3.30 p.m.	Break	
	Chairman: S. K. Jain	
3.30-4.15 p.m.	Solar wind and magnetospheric processes and various coupling mechanisms, including those observed on other planets	C. A. Reddy (India)
4.15-4.45 p.m.	Helium radiation diffusion in prominences with variable electron density: theoretical contours of the Lambda 584 resonance line HeI	Ch. Lkhagvazhav (Mongolia)
4.45-5.30 p.m.	Open discussion	
	Special session SAA-1: Space astronomy and astrophysics	
	Chairman: G. Swarup	
1.45-2.30 p.m.	Galaxies and stars: basic building blocks of the universe?	Y. Chu (China)
2.30-3.15 p.m.	The primeval fireball as seen by COBE	R. Sinha (NASA)
3.15-3.30 p.m.	Break	
3.30-4.15 p.m.	Open discussion	

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DATE/TIME	SUBJECT	SPEAKER
1 MAY 1991	Plenary session 3: Status of space science	
	Chairman: A. M. Mathai	
9-9.45 a.m.	Japan's contribution to the international space research programme leading to the Solar-A mission	Y. Kuroda (Japan)
9.45-10.30 a.m.	The current status and future focus of basic space science in India	K. Kasturirangan (India)
10.30-10.45 a.m.	Break	
10.45-11.30 a.m.	UV-B measurements in India	B. S. N. Prasad (India)
11.30 a.m.-12.15 p.m.	The International Ultraviolet Explorer Project (IUE)	W. Wamsteker (ESA)
12.15-1 p.m.	Biosphere-geosphere interactive processes	A. P. Mitra (India)
1-2 p.m.	Lunch hosted by the Director, Indian Institute of Astrophysics, Bangalore, at Workshop venue	
	Special session SSS-2: Solar system science	
	Chairman: H. A. Hill	
2-2.45 p.m.	Equatorial electrojet and spread-F phenomena	C. A. Onwumechili (United Kingdom)
2.45-3.30 p.m.	Climatic variability brought about by global change	B. Hidayat (Indonesia)
3.30-3.45 p.m.	Break	

DATE/TIME	SUBJECT	SPEAKER
	Chairman: H. J. Haubold	
3.45-4.30 p.m.	Interplanetary disturbance structures and geomagnetic storm	G. L. Zhang (China)
4.30-5.30 p.m.	Long-term solar variability and solar seismology: II	H. A. Hill (United States of America)
	Special session SAA-2: Space astronomy and astrophysics	
	Chairman: R. Sinha	
2-2.45 p.m.	The role of space-based observations in astrophysical research	J. Grygar (Czechoslovakia)
2.45-3.30 p.m.	Radio astronomy: review and recent developments	G. Swarup (India)
3.30-3.45 p.m.	Break	
3.45-4.30 p.m.	Neutrino and gravitational wave astronomy	H. J. Haubold (United Nations)
4.30-5 p.m.	Effects of nuclear collisions in extragalactic radio sources (EGRS)	P. N. Okeke (Nigeria)
5-5.30 p.m.	Open discussion	
2 MAY 1991	Plenary session 4: Space missions	
	Chairman: W. Wamsteker	
9-9.45 a.m.	Astronomical research in Japan	Y. Kozai (Japan)
9.45-10.30 a.m.	The Cosmic Background Explorer: its perspectives	R. Sinha (NASA)
10.30-10.45 a.m.	Break	

DATE/TIME	SUBJECT	SPEAKER
10.45-11.30 a.m.	The search for life beyond Earth	R. Khanna (United States of America)
11.30 a.m.-12.15 p.m.	Working Group session Chairman: W. Wamsteker Rapporteurs: H. S. Gurm, S. C. Chakravarty	
12.15-1.45 p.m.	Lunch at Workshop venue	
1.45-3.15 p.m.	Working Group session (continued)	
3.15-3.30 p.m.	Break	
3.30-5 p.m.	Working Group session (continued)	
3 MAY 1991	Plenary session 5: Conclusions	
9-10.45 a.m.	Working Group session (continued)	
10.45-11 a.m.	Break	
11 a.m.-12.15 p.m.	Closing session Chairman: K. Kasturirangan Rapporteur: H. J. Haubold 1. Report by Chairman of Working Group. 2. Adoption of the report. 3. Presentation on ISRO and closing remarks by U. R. Rao.	
12.15-1.15 p.m.	Lunch	
1.15-5.45 p.m.	Visit to ISRO facilities	

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